known circumstance to those persons who inhabit the country, however unenlightened ornithologists may be in the matter. It furnishes a case parallel with that related by Audubon, of the herring gull nesting in communities, in trees.

I will conclude with an observation on the digestive arrangements of the sage cock—a bird which I have only lately seen alive. It has been repeatedly stated to feed exclusively upon sage leaves. All those I shot had the craw full of grasshoppers and other insects, and had nothing else in it. It has also been asserted that the bird has no gizzard; the gizzard is indeed quite thin, so as to appear merely a membranous bag, but for all I could see that the disposition of the muscles is the same as that obtaining in other gallinaceous birds. The case is simply a reduction of the amount of muscle, without any essential change in arrangement. At least this is the result of an off-hand dissection, such as one would be likely to make in the field. The change is an evident adaptation to the soft and succulent or juicy nature of the bird's food—buds, leaves and insects, instead of grain. There is another peculiarity of this bird, also dependent upon its food, and the nature of the digestive process. When flushed it almost invariably acts in the way which has given the green heron (*Ardea virescens*) its inelegant popular appellation.—*Milk River, at* 49°, *July* 25, 1874.

THE METAMORPHOSIS OF FLIES.* I.

BY DR. AUGUST WEISSMAN.

Before I pass to the general results of the foregoing observations a short chronological exhibit of all the processes of development will be useful.

In agreement with all the earlier observations on the embryology of other insects it is apparent that during the life of the larva, in its outer form as well as the internal organs, only the

*Though Weissman's famous work, "The Development of Diptera," was published as long ago as 1864, yet we feel sure our readers will value the translation of a few of the concluding chapters which have not previously been rendered into English. The present chapter is entitled "View of the Phenomena of Development."—A. S. P.

phenomena of growth are manifested, and not a deeper reaching metamorphosis. As the enlargement of an organ by simple growth in the Vertebrates is allied with a new formation of blood vessels, so here the origin of a new trachea is accompanied by the speedy enlargement of muscles and intestine, and with this very important continual increase of the net-work of tracheæ is combined an expansion and increase in volume, so that after the first moulting, on the anterior end of the body, a new pair of stigmata are formed, while the aperture in the hinder one is doubled, and after a second moulting, a three-fold aperture is made. Accompanying this is a certain change in the apparatus of hooks arming the mouth of the larva. All these changes are not of great importance; they lead to no new feature in the organization of the animal; they are series of processes which precede the formation of entirely new organs or parts. Transformation in this last sense occurs only in those parts of the larva, out of which the parts of the adult insects are developed. *The genital glands, as well as the outer skin of the segments bearing the appendages of the fly's body, are already formed in the larva; indeed they are even formed during the development of the embryo.*

We find ourselves in fact almost going back to the encasement theory of Swammerdam, who believed that the larva, pupa and butterfly were imprisoned from the very first in each other, and came to light by the successive casting off of each skin. It is in fact only this, that the parts of the fly* do not all lie perfectly formed within the larva, but exist only as rudiments, and that only a part of the body of the fly is newly formed, while some of the parts will be produced out of the larva. The head and thorax with their appendages are formed within the larva by the gradual development of special cell masses. The abdomen, however, arises through a simple change of a number of larval segments. The head and thorax arise not as a whole out of a single cell mass, but in separate pieces, out of which after pupation the whole form is perfected.

The head arises out of two groups of cells which originate from a nervous filament sent off from the supra-œsophageal ganglion; but each segment of the thorax arises out of four separate groups of cells which are partly inserted in the course of a slender filament, and are in part blended with the peritoneal skin of a trachea.

* This chapter relates wholly to *Musca vomitoria.*

These collections of cells form flat disk-like bodies which are enclosed in a structureless membrane and may be termed the *imaginal disks*. In each imaginal disk of the thorax arises a quarter of a segment with the appendage belonging to it; the two imaginal disks of the head, the appendages of the brain, unite themselves into a hinder division, the eye-disks; and an anterior which forms the germ of the antennæ and remaining portion of the head.

The pupation in Sarcophaga occurs eight or ten days after the exclusion of the larva from the egg. It is accompanied by a marked contraction of the whole body, with an infolding of the first segments.

Under the hardened, barrel-shaped, larva skin [puparium], the true pupa is formed, *i. e.*, the body of the fly enclosed by a special membrane, the pupa-sheath. The process of formation of the body of the fly, while thus enclosed, lasts for four days after the pupation. Then it reaches that stage which in the development of the butterfly is shown by a stripping off of the larva skin, and the *formation* of the pupa is ended; then begins the *development* of the same. This consists in the building up of the external form of the body, and in establishing the position and development of the internal organs. This period can be divided into two sections, which are here described chronologically. The first division consists of the more delicate modelling of the outer form. Hitherto the insect has appeared only in its crudest shape, the appendages of the thorax and head are but rudimentary, neither attaining their full size, nor their definitive form. All these parts are now entirely formed, and are matured in from two to seven days, and already covered with colorless hairs and bristles.

The second division covers the period of the eighth to the twentieth day, during which time the inner organs are completed, and the outer surface of the body assumes its peculiar colors.

The first period, that of the formation of the pupa, lasting from one to four days, begins with the destruction of the four anterior segments of the larva. The hypodermis which gives it its form is loosened, the muscles of the body-walls, as also of the pharynx, the cellular walls of the pharynx itself, the anterior part of the œsophagus, with the sucking stomach, follow next. During this time the thoracic pieces are developed from the imaginal disks; they give origin to the appendages, which are indeed very short, but still each joint can be distinguished, and are nothing but a

projection outwards of these same thoracic pieces. However here — as we had until now thought — the appendages of the imago do not result from a simple thrusting out of the larval hypodermis, as would seem to be correct in a morphological view, which would consider the appendages of the insectean body as projections of the skin, during their development not aborted, but persistent. They are in fact still, however, projections outwards of the skin, though they are formed at a time when the skin has not grown into closed segments. Still we find at the end of the second day the formative disks of the thorax appended to their pedicels (nerves, tracheæ) in the form of swollen transparent vesicles, and within them the thoracic pieces to which they are closely related, with its appendage, can be easily observed. In three days they have attained their perfection, the skin peels off and falls away, and they now become three completed rings, the thoracic segments. At the same time the tracheæ of the larva are thrown off, and then begins the formation of a peculiar tracheary system, which performs its functions only during the pupal period. In its trunks and larger branches it resembles the larval system, but in the terminal rings is unlike anything else. In this respect their structure is very peculiar, in that all the ends project freely into the liquids of the body, and nowhere, as before, do they send fine branches to the different organs. The filling of the new system of air vessels with air does not go on during the remaining moultings, through a removal of the old proximal tubes (*intimaröhren*); this cannot be completely seen during the life of the pupa, but through the cross division of the proximal tubes (*intimaröhren*) in a determined place of the stem near the anterior stigmata.

At the third day the three segments of the thorax unite to form a small ring which posteriorly coalesces with the edge of the fifth larval segment; but the anterior edges are puffed up and are open. In the opening lie loose the chitinous parts of the mouth parts, the apparatus of hooks. The head of the fly is not yet to be seen, but the rudiments of the same are still visible within the thorax. In the two formative disks of the body, which we would consider as appendages to the brain, develop into a vesicle containing the œsophagal ganglion, the head-vesicle, on which the eyes and antennæ are already indicated, and from under whose hinder edge the proboscis grows out. On the fourth day the head, which has advanced forwards from within the thorax, comes to light, and is

accompanied by an uninterrupted, strong contraction of the eight hinder segments of the larva still contained within. These last are shortened, and soon assume the form of the abdomen of the adult fly. The head thus presses forwards out of the thorax, keeps pace in development with the thorax; the body of the pupa then lies as a whole contained within the puparium, and thus indicates the end of the first period.

The process of development of the first four days is confined not wholly to the outer crust of the body, but also to the new remodelling, or transformations of some of the inner organs. The nervous centres which had been separated in the larva here become united; an infra-œsophageal ganglion separates (abschnürt) from the ventral cord, and the upper (supra-œsophageal ganglion) divides into two divisions, of which the outer may be considered the central organ of the sense of sight (ganglion opticum) and as the bulb of the compound eyes.

All the anterior and middle portion of the alimentary canal sloughs off, and at the end of four days becomes renewed. This happens only to the œsophagus and chyle-stomach, while the proventricalus and cæcal appendages of the stomach are not thus reproduced. They break up cell by cell; these cells are carried into the chyle-stomach forming there a compact mass, which is surrounded with a peculiar covering, as if encysted. They do not fill up the cavity, but swim in a honey-like liquid which by this time will have been secreted by the cells of the walls. Here the cells are preserved, though the organ is destroyed, thus the reconversion is effected in the walls of the chyle-stomach. Each cell decays by fatty degeneration and in the place of the old cells arise new ones which rebuild the organ. The destruction of the cells is accompanied by a contraction of the muscular walls, and thereby an important shortening of the organ is produced. Next these muscles as well as the tracheæ decay, many branches of which are interwoven around the stomach of the larva; the alimentary canal remains without air-vessels until the last day of the pupa state. As soon as the abdomen has formed, by the contraction of the subcutaneous muscles of the last eight larval segments, the muscles disappear, and at the same time, namely, during the advance of the head, at which time also the nervous centres become pushed forward; they tear away also the degenerated nervous branches, whose terminal threads likewise become

destroyed with the organs in which they ramify. Of the influence of the nervous system on the entire organism, there is nothing to be said since the change of form of the central parts is accompanied by a complete histological transformation, as the interpenetration of their cell masses with fat demonstrates.

The dorsal vessel does not now perform its functions. The animal now consists of a thin cellulose skin, with its contents partly destroyed, in part completely destroyed, and in part already concerned in the new formation of the organs. The entire fat body, cellulose tissue, of the larva, is lost in a liquid mass of fat globules and nuclei, and they are mingled with the decaying muscles, tracheæ, etc. At the end of the first period the contents of the pupal body may be well compared with the contents of the fertilized egg. All visible traces of animal life have ceased; the action of the centres of the expression of animal life is suspended, and out of this chaos of elemental parts the organs are built up anew. One essential difference from the development of the embryo only remains, that at no time are all the inner organs wanting. External activity and decay occur simultaneously. But any internal or external movements are wanting; sense organs and nerves are wanting, and there can be truly said to be no outward impressions received, though an activity may be ascribed to the central parts of the nervous system. Yet a regular flow of fluids does not occur, and the only relative physiological action is that of breathing, *which here goes on as passively as in the egg;* in the one case through the stigmata and tracheæ, in the other by the pores of the egg-shell. An active breathing process, such as goes on in the perfect state, is entirely wanting.

While the decay of the inner organs is going on, or has already taken place, the formative elements begin to develop themselves out of the cell-mass; fat nuclei, fat globules, and flakes of stearine unite into round masses of nucleated spheres, which are capable of building up a membrane around themselves, and embracing a nucleus within. Already in the third, still more in the course of the fourth, day do the appendages of the thorax grow in length, and all arise from a thin cellulose skin, and out of a larval cavity which fills up with fat globules and nuclei as the fat body gradually breaks up. With this begins the metamorphosis of the appendages and of the external form of the body into their definitive form; the period of formation of the body of the pupa

has ended, and now begins the *period of development of the same.* It lasts from the fifth day to the time of exclusion of the fly, and can, as has already been shown above, be divided into two subdivisions, of which the first reaches to the end of the seventh day.

First to be noticed is the formation of the pupa-case, which, however, was in existence at the end of the first period, but lies as the cuticula right on the cellular skin (zellenrinde) by which it was ensheathed. It now rises up and a space filled with clear liquid separates it from the upper surface of the body. The cellular tegument (zellenrinde) of the appendages is thickened, partly by the increase of the cells present, which seem to receive their plastic material by endosmose, but partly through a free formation of new cells by a self division of the nuclei. The whole cavity of the limbs seem to be compactly filled with nuclei which are uniformly from the outer to the innermost transformed into cells.

By the fifth day the last tarsal joint is divided into two lobes, and show the first position of the claws. On the sixth the sutures are more distinct, the pulvilli are formed, and on the seventh day the external form of the limb is completed. The hypodermis divides into two layers whose deeper portion is disposed on the upper surface of the skin and form the hairs and bristles. Inside the limbs only the position of the nerves and tracheæ of the pupa is established, the muscles arise afterwards.

In like manner the wings are formed, their veins arise, the hairs appear; they attain their definitive form and are folded together.

The halteres grow out, and instead of a single hollow, stunted projection, they are completely formed, and hairy, though still colorless. The antennæ also reach the same grade of perfection, and like the appendages, the segments themselves now assume their definite form. The four abdominal segments are formed out of the eight larval segments which originally formed the abdomen of the fly.

While the external form of the body rapidly advances in this manner to its final perfection, corresponding but slower changes are discovered in the viscera. The fatty tissues continually disappear, and as often the cavity of the body is filled more compactly with nucleolated cells, and fat molecules. The newly formed thin œsophagus thickens at the end towards the proventriculus, and indeed the first beginnings of the sucking stomach is indicated at

this period. The chyle-stomach gradually changes in length, its walls are transparent and clear, and it is strikingly demarked from the dark small intestine rendered so by the walls filled with fat corpuscles. With this begins the period of decay, and it reaches on the seventh day its complete development.

Already during the course of seven days usually begins the *second subdivision of the second period* which is characterized by the relative position and development of all the organs of the imago. On the seventh day we find in the cavity of the thorax the first trace of the muscles of the wing. Series of cells of the greatest fineness pass in determinate directions through the liquid masses of fat, and up to the fourteenth day increase in thickness, until finally they lie close together to the lateral spaces of the thorax, and only leave in the median line a slight space for the free passage of the stomach. Their structure is, then, usually definitive, it is a sarcolemmous sheath filled with contracted fibres which lie together in fascicles, and are kept separate from one another by nucleated columns. Meanwhile out of the fragments of the old intestinal canal appears the new, and shortly after this is accomplished there is a union of the small intestine and rectum, and by the tenth day the rectal pouch is placed in relation with the four rectal apillæ. At the same time a new plexus of muscles begins to form on the upper side of the entire intestinal tract.

Still the most important steps in the formation of the principal organs of sense of the fly, the compound eyes, fall into this last section of its developmental history. The ocular disks, which originated out of the hinder division of the brain-appendage, is still connected with the bulb at the beginning of the second period by means of a slender nerve. The bulb gradually extends itself so that it covers the whole interior of the eye-disk, and only becomes separated from it by a thin layer of fat, which has already arisen between the two parts. The bulb shows radiating streaks, which are indications of the nervous threads passing through it. Only out of the eye-disks will the true eyes be formed, *i. e.*, the compartments with the dioptric apparatus, and the perceptive nervous elements. On the twelth day, however, the disks and also each compartment leading out of it, have the very small diameter of 0·051 ^{mm}., which is gradually at the close of the pupa state enlarged five times, while at the same time the cellular elements lying behind each corneous facet, forms for each chamber a crys-

talline body, a nervous thread and cortical substance. The pigment layer begins to form and is finished, and the bulb sends out the ganglion cells at the base of the chambers of the eye. The nervous centres also take on their last definite form, the hinder part of the ventral cord, which already in the first period had extended out from the infra-œsophageal ganglion, and had extended back into the abdomen, now unites with the thoracic knot. A similar longitudinal commissure unites it with the infra-œsophageal ganglion. At the last moment the central portions send out nerves to the sides into the thoracic muscles and into the limbs, in which during the tenth and eleventh day the muscles begin to form, and afterwards hindwards into the abdomen.

Of the larval organs only the dorsal vessel is destined to pass over into the last division of the developmental period, but it still suffers a total transformation. A process of fatty degeneration similar to that which took place in the alimentary canal occurs, and on the 12th day it assumes a new form and organization. Meanwhile it is not capable of performing its functions, as the want of a histologically perfect system of muscles proves.

The tracheary system is completed last of all. The first positive condition is assumed on the 15th day, and by the 17th it is generally entirely formed. The trunks arise for the most part by means of the masses of nuclei out of the originally solid series of cells, the terminal branches of the organ out of a single cell; the hollow space between them will form the cavity of the trachea, while they branch out by growing outwards. Yet these cells may for the most part be traced back to the masses of nuclei, but soon and especially within the inner of the bundles of primitive muscles of the thorax, *they arise from an organization of the histological formative elements at hand, i e. the muscular nuclei.* This remarkable fact does not take place without a reaction in the muscular fasciculæ themselves; their sarcolemma disappears and they deteriorate into fascicles of tracheæ wanting the spiral thread.

All the organs which have tracheæ intimately connected with them have the same developed in the last three days. The tracheæ grow out in the nervous centres, in the bulb of the eyes, and the alimentary canal in its entire course is surrounded by a net work of them. They are sent to the rectal papillæ in great abundance and with a peculiar development. The dorsal vessel also and the entire muscular system receives tracheæ and likewise the genital cavities with their outlets and accessory apparatus.

As the development of the genital glands has already begun during the larval state, so during all the pupa state it steadily goes on, the copulatory pouch, the accessory glands, and *receptaculum seminis*, are developed with the new alimentary canal in the last section of the period of development. The genital glands of the male only attain their development during the pupal state. The eggs are developed directly after the exclusion of the fly.

The final perfection of the external form is the coloring of the chitinous skin. Shortly after, on the 18th to 20th day, follows the hatching of the egg.

ADDRESS OF PROFESSOR JOSEPH LOVERING.*

GENTLEMEN AND LADIES OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—

WHEN the States General of France were assembled for the last time at Versailles, after a long interval of inactivity, and an inaugural address was pronounced by the Bishop of Nancy, Mirabeau passed upon his performance the sweeping criticism that he had missed the grandest opportunity ever offered to man for saying something or holding his tongue. And, whenever this Association, comprising not only those who teach, but many who create science, assembles, as it now does, to listen to the address of its retiring President, if he is duly sensible of his responsibility, he would gladly avail himself of Mirabeau's alternative, either of being equal to the occasion or of being silent. But the rule of the Association, adopted in the original draft of the constitution at Philadelphia, and the example of my predecessors which I am unwilling to reverse, leave me no choice; and when I see around me, not the terrible monsters of the French revolution, maddened by the miseries of a downtrodden country, but calm and high-minded lovers of truth, I feel sure of a just and generous criticism. Welcome, then, the precious opportunity, enjoyed by the President

*The retiring President of the American Association for the Advancement of Science, delivered at the Hartford meeting.